

Oviphagous Embryos of the Pseudocarchariid Shark, *Pseudocarcharias kamoharai*, from the Central Pacific

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Abstract Eleven specimens of *Pseudocarcharias kamoharai*, consisting of 8 males and 3 females, were collected from the central Pacific in June, 1979. One of the females, 985 mm TL, was pregnant and contained four large embryos (401~428 mm TL) in the uteri. The embryos had no trace of umbilical scar. But, their abdomens were distended and, when dissected, their stomachs contained considerable amount of egg yolk material which accounted for about 25% of the weight of the body. This suggests that the embryos of *P. kamoharai* nourish themselves by feeding on ova in the uteri of the female. Another pregnant female, 982 mm in TL, contained both small embryos (37.9~40.8 mm TL) with yolk sacs and many egg capsules in the uteri. These small embryos had still been absorbing yolk material from the yolk sac, and showed no signs of feeding on ova in the uteri.

The Pseudocarchariid shark, *Pseudocarcharias kamoharai* (Matsubara), was first described from Japanese waters by Matsubara (1936). Since then several authors have reported it from various seas, viz. off Taiwan (Teng, 1959), off Guiana coast (Cadenat, 1963), off Cape Town (D'Aubrey, 1964b), and the Pacific Ocean (Sivasubramaniam, 1963; Abe et al., 1969; Abe, 1973). According to D'Aubrey (1964b), *P. kamoharai* is widely distributed, but specimens so far recorded are scarce in number and only a few references concerning biological observations are found.

In June, 1979, I collected 11 specimens of *P. kamoharai* on board the training vessel Kashimamaru of Ibaragi Fishery High School during a fishery survey of the central Pacific. Examination of these specimens revealed the occurrence of oviphagy in the embryos of *P. kamoharai*.

Materials and methods

A total of 11 specimens of *Pseudocarcharias kamoharai* comprising 8 males and 3 females were collected in the central Pacific by tuna longline (Fig. 1). The operations of longline were mostly carried out about 180 m below the surface. The gear was set between 04:00 and 08:30, and hauled up before 24:00 in each operation. The saury, *Colorabis saira*, and chub mackerel, *Scomber japonicus*, used as bait, were attached to 2160 hooks per longline set. Female specimens were dissected on board, and small

embryos and egg capsules in their uteri were fixed in 70% ethyl alcohol and large embryos were frozen at -60°C . The stations of the operation where *P. kamoharai* were hooked are shown in Table 1.

Results

One pregnant female, 982 mm in total length (TL), captured at $13^{\circ}08'N$, $167^{\circ}59'W$ on June 5, 1979, contained both egg capsules and small embryos in the uteri (Fig. 2). Two embryos, 38.2 mm and 40.0 mm TL, and 21 egg capsules were found in the right uterus. In addition, two embryos, 37.9 mm and 40.8 mm TL, and 23 egg capsules were present in the left uterus. These embryos were yellowish white in color, except for the eyes, which were pigmented by melanophores. All fins were developed. Long external gill filaments extended from the spiracles and gill-slits (Fig. 3). Jaw teeth and dermal denticles on the skin had not yet developed. All of the embryos had a small external yolk sac hanging by a short stalk from the thorax. One of the embryos, 37.9 mm TL, had a yolk sac measuring 8.5 mm long and 2.5 mm wide. The yolk stalk penetrated into the thorax between the pectoral fins and reached to the colon in the abdominal cavity. The colon with developed spiral valves was filled with yolk material supplied from the external yolk sac. The stomach was not distended and empty. It seems that the stomach does not function in the utilization of the egg yolk

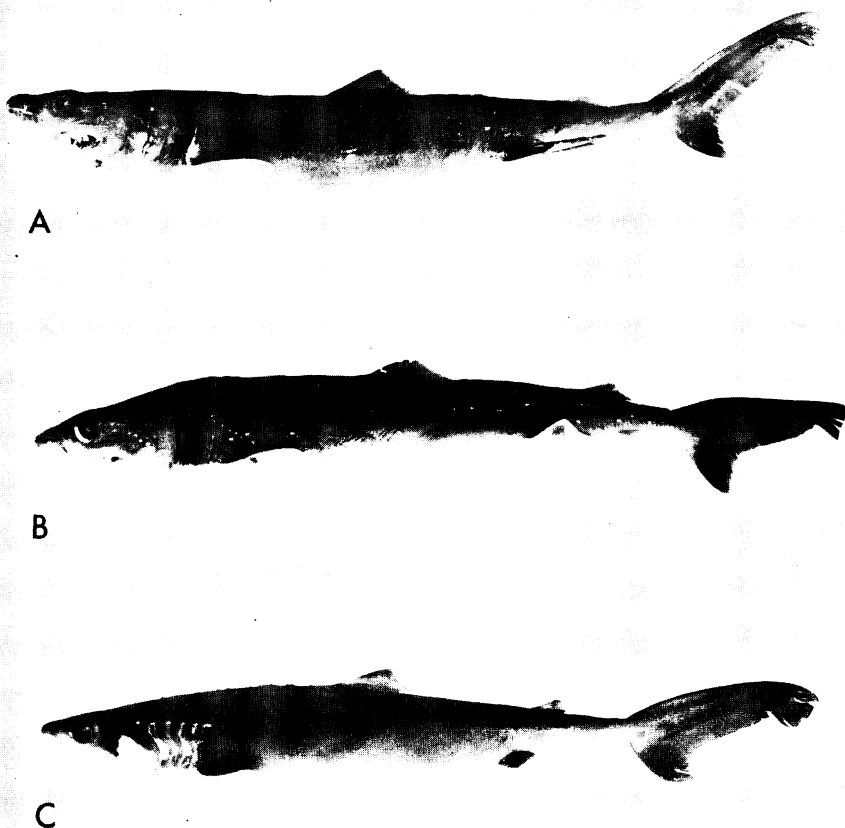


Fig. 1. *P. kamoharai*, collected from the central Pacific by the Kashima-maru, in June, 1979. A: A male, 935 mm TL. B: A female, 977 mm TL. C: A female embryo, 428 mm TL, obtained from a pregnant female *P. kamoharai*, 982 mm TL.

Table 1. Location of tuna-longline stations operated by the Kashima-maru of Ibaragi Fishery High School in the central Pacific where *P. kamoharai* were collected with water temperature at the stations.

Date	Location		Water temperature (°C) at different depths										Number of specimens	
	Lat(N)	Long(W)	0 m	25 m	50 m	75 m	100 m	125 m	150 m	175 m	200 m	male	female	
June 5, 1979	13°08'	167°59'	26.8	26.8	26.8	26.5	26.2	24.2	21.2	18.2	15.4	1	1	
June 10, 1979	11°26'	166°43'	26.9	27.0	27.0	27.0	25.6	21.8	19.4	15.6	12.4		2	
June 22, 1979	18°47'	161°16'	26.2	26.2	26.2	24.5	23.5	22.4	21.6	19.9	18.4	1		
June 23, 1979	18°38'	161°36'	26.0	26.1	26.1	25.4	24.4	23.5	21.8	20.6	19.1	1		
June 24, 1979	18°31'	161°50'	26.0	26.1	25.7	24.8	24.2	23.7	23.1	22.1	20.4	1		
June 25, 1979	18°28'	161°35'	26.1	26.0	26.0	24.9	24.0	22.9	21.9	20.5	19.4	1		
June 26, 1979	18°25'	161°24'	26.2	26.2	26.2	25.3	24.4	23.1	21.4	20.4	19.4	2		
June 29, 1979	18°55'	163°10'	26.0	26.1	26.1	25.0	24.2	23.9	23.4	22.5	20.5	1		

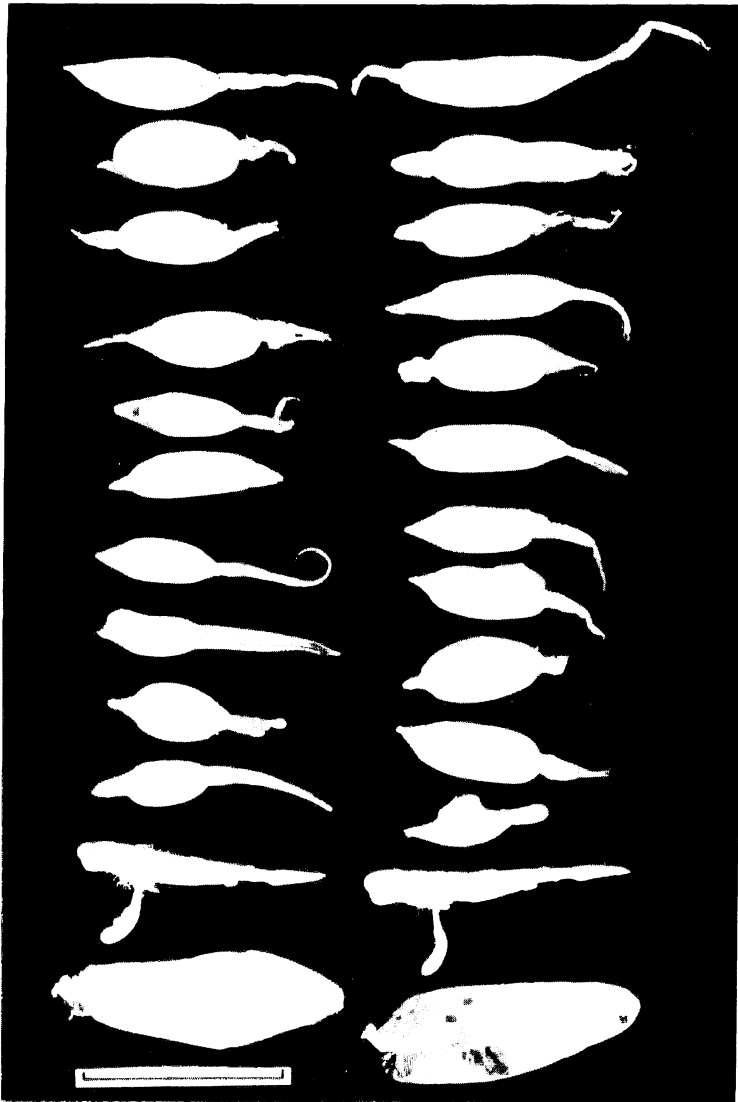


Fig. 2. Small embryos and egg capsules in the right uterus of a pregnant female *P. kamoharai*, 982 mm TL. Scale indicates 30 mm.

in the uterus as food at this stage.

Egg capsules were thin-walled and brittle as seen in *Odontaspis taurus* described by Springer (1948), pale yellowish brown in color, semi-transparent, and varying in size. One of them, 37.0 mm long and 7.5 mm across at the widest point of the yolk part, was oval in shape at the yolk part; one end of the capsule was formed into a short projection and blind while the other formed a long twisted projection possibly with a mouth at the tip. Each of the egg capsules contained

more than one egg (Fig. 3). The number of ova in each of 15 egg capsules examined varied from 2 to 9. It could not be determined whether the ova in egg capsules had been fertilized. A considerable amount of yolk material was observed in the ovary of the mother.

Two females, 977 mm and 985 mm TL, were captured at 11°26'N, 166°43'W on June 10, 1979. One of them, 985 mm TL, was pregnant and contained four large embryos, two in each uterus. One of the embryos was a male

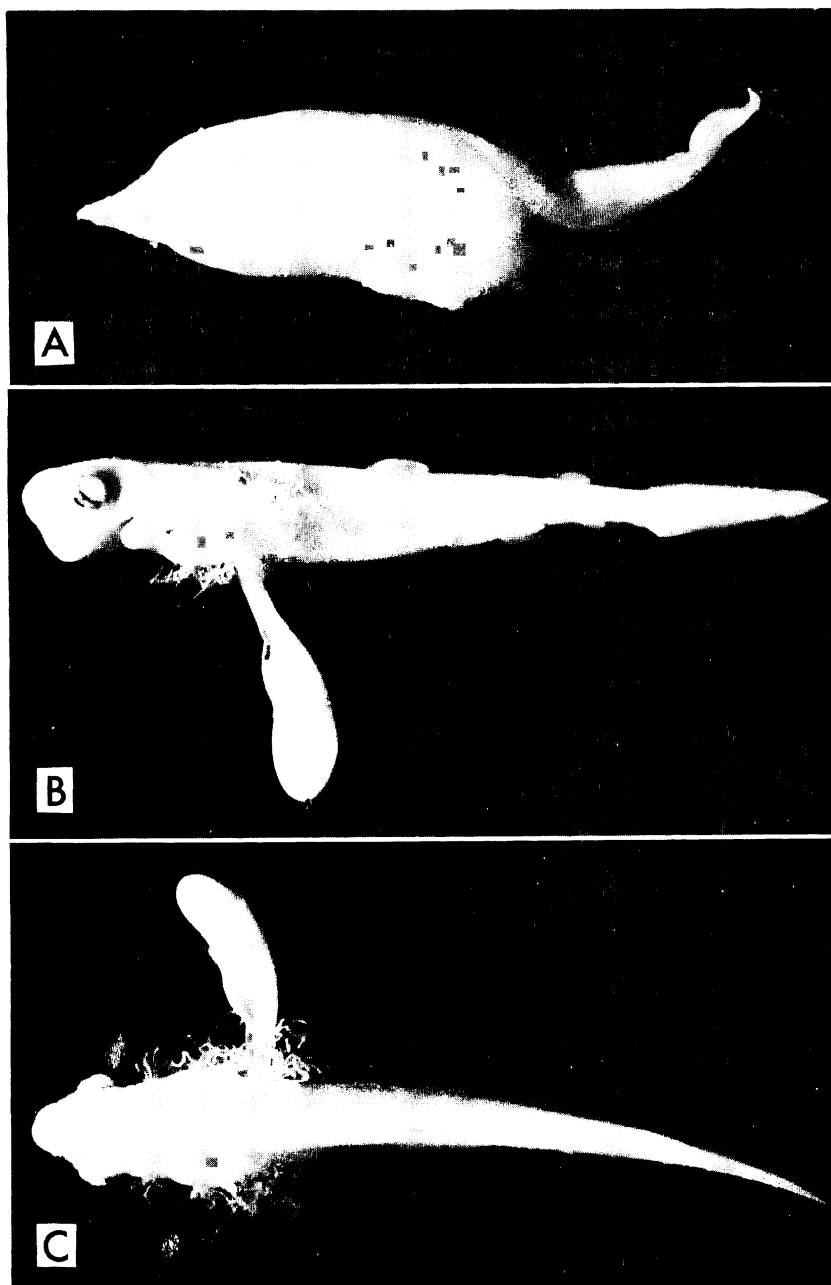


Fig. 3. An egg capsule and small embryo obtained from a pregnant female *P. kamoharai*, 982 mm TL. A: An egg capsule which contains six ova. B: Lateral view of a small embryo, 38.2 mm TL, with a yolk sac and external gill filaments. C: Dorsal view of the embryo.

and the remaining three were females. The sizes of the embryos were as follows: male, 403 mm; females, 401, 404 and 428 mm TL.

These embryos were moving actively in the

uteri when the adult was dissected on board. The color of the live embryos was dark brown on the dorso-lateral side and white on the ventral side from the mouth to the base of the caudal

Fujita: Oviphagous Shark Embryos

Table 2. Measurements, dentition, and proportional dimensions of embryos and adults of *P. kamoharai* collected from the central Pacific.

Character	Embryo				Adult		
	Male	Female	Female	Female	Male	Male	Female
Total length (mm)	403	401	404	428	930	864	977
Proportional measurements in TL							
Length, snout to 1st dorsal origin	2.7	2.6	2.5	2.7	2.5	2.6	2.6
2nd dorsal origin	1.6	1.5	1.5	1.6	1.5	1.5	1.5
pelvic origin	1.8	1.7	1.7	1.7	1.8	1.7	1.7
anal origin	1.5	1.5	1.4	1.5	1.4	1.4	1.4
pectoral origin	4.6	4.5	4.4	4.6	4.3	4.3	4.3
upper end 1st gill slit	5.8	5.6	5.6	6.1	5.4	5.5	5.3
upper end 5th gill slit	4.4	4.2	4.2	4.3	4.1	4.2	4.1
anterior margin of eye	15.2	15.7	15.4	15.0	14.1	14.8	14.8
inner end of nostril	23.5	22.3	22.2	23.2	17.6	18.8	18.4
mandible	15.7	16.0	14.9	16.2	12.9	12.8	13.6
Nostril length	85.9	77.1	86.0	77.9	71.6	75.3	75.2
Internasal distance	42.9	36.5	36.7	40.8	43.3	45.5	46.6
Horizontal orbit diameter	37.4	32.3	36.1	31.7	34.5	34.6	36.2
Interorbital distance	21.4	19.9	20.1	21.9	22.3	23.2	23.3
Mouth width	16.2	16.0	16.4	16.8	15.5	18.0	17.9
Length, from orbit to spiracle	28.8	26.7	27.3	27.7	27.2	25.4	28.3
Length, 1st gill slit	17.5	15.3	19.2	17.1	19.8	18.4	17.8
3rd gill slit	17.5	18.2	17.1	16.8	17.8	17.6	17.5
5th gill slit	15.6	15.0	16.3	16.1	18.6	19.0	17.3
Between upper ends, 1st to 5th gill slit	16.1	14.1	15.5	14.4	15.5	15.6	17.3
Interdorsal distance	5.2	5.7	5.8	5.8	5.2	5.3	5.5
Between fin fronts, 1st to 2nd dorsal	3.6	3.7	3.9	3.9	3.6	3.7	3.7
2nd dorsal to caudal origin	9.3	9.2	9.1	8.8	8.2	9.2	8.3
pectoral to pelvic	2.9	2.6	2.8	2.6	2.9	2.8	2.8
anal to lower caudal origin	13.6	12.9	12.1	12.6	11.0	11.9	12.3
Length, 1st dorsal base	11.0	10.7	11.9	12.3	11.5	10.7	10.6
2nd dorsal base	25.4	25.1	27.9	22.1	23.0	23.7	24.8
anal base	36.7	39.3	40.8	42.9	35.5	45.5	42.5
Pectoral length	10.8	10.8	10.9	11.0	10.0	9.8	10.6
Length, caudal upper lobe from origin to tip	4.0	4.2	4.1	4.0	4.5	4.3	4.5
lower lobe from origin to tip	9.3	9.8	9.5	9.7	10.0	9.1	9.9
terminal lobe from notch to tip	14.4	16.4	14.1	14.6	19.6	18.9	20.2
Depth, caudal peduncle	44.3	38.9	37.4	38.6	43.1	42.8	41.6
Dentition	11-1-2- 2-1-12	12-1-2- 2-1-12	12-1-2- 2-1-11	11-1-2- 2-1-10	9-1-2- 2-1-10	10-1-2- 2-1-11	10-1-2- 2-1-10
	11-2-2-11	11-2-2-10	10-2-2-9	9-2-2-9	7-2-2-11	10-2-2-10	10-2-2-10

fin. White blotches were present on the cheek and behind each gill-slit, though they were absent in the adult specimens. The posterior margins of all of the fins were opaque white.

The skin of the embryos was rough with developed denticles, and the teeth on the jaws were sharp, strong, and well developed as in the adults. A small spiracle was present between the

posterior margin of the eye and the first gill-slit. The embryos had no trace of umbilical scar. In Table 2, tooth counts and proportional dimensions of the embryos are listed and compared with those of the adult specimens. Morphometric measurements of the embryos agree in general with those of the adults.

The abdomens of the embryos were greatly distended and, when dissected, their stomachs were found full of egg yolk material, but contained no fragments of egg capsules.

The stomach of one female embryo (401 mm TL, weighing 307 g) contained about 75 g of egg yolk material, accounting for 24% of the total weight of the body. In another female embryo, 404 mm TL and weighing 295 g, the stomach contained about 72 g of egg yolk material which occupied 24.4% of the total weight. This amount is equivalent to the amount of yolk material from 107~112 egg capsules.

The other adult female, 977 mm TL, contained no embryos and no egg capsules in the uteri. But the uterine membrane was fairly expanded and thin, suggesting a possibility that this female gave birth shortly before the capture.

Discussion

In contrast with most other ovoviviparous sharks, the yolk sac in oviphagous species is absorbed and the umbilical cord entirely disappears when the embryos are still very small. After that, the embryos nourish themselves by feeding on ova present in the same uteri until their birth, resulting in forming yolk stomachs (Bigelow and Schroeder, 1948). Such oviphagous habits have been observed in some species of sharks; the short finned mako, *Isurus oxyrinchus*, family Isuridae (Vaillant, 1899; Cadenat, 1956; D'Aubrey, 1964a; Gubanov, 1978, stating this shark is viviparous); the porbeagle, *Lamna nasus*, family Isuridae (Bigelow and Schroeder, 1948); the sand shark, *Odontaspis taurus*, family Odontaspidae (Springer, 1948); and the thresher shark, *Alopias vulpinus*, family Alopiidae (Gubanov, 1972).

Concerning the breeding season of *Pseudocarcharias kamoharai*, only two pregnant females have been recorded. Abe (1973) described a pregnant female, 99 cm in total length, captured from the eastern Pacific by tuna-longline early in spring, 1972. Another female was caught in

the southwest Indian Ocean in July, 1964 (Bass et al., 1975). The present pregnant specimens were caught in the central Pacific during June, 1979. These data are sporadic and insufficient to define the reproductive season of this shark. However, the striking differences in the size of embryos between the two pregnant females under study suggests that the mating season extends for a long term. Bass et al. (1975) showed that the mating season of *Odontaspis taurus* from Natal Coast ranged from October to December. In *Alopias vulpinus* from the northwest Indian Ocean, Gubanov (1972) reported that mating is not confined to any definite season.

According to Abe (1973) and Bass et al. (1975), the litter size of *P. kamoharai* is small, consisting of four embryos, two in each uterus. The present females also contained four embryos, two in each uterus, respectively. The number of embryos in a brood is small in all oviphagous species. In *O. taurus* one brood consists of two embryos, one in each uterus (Cadenat, 1956; Sadowsky, 1970; Bass et al., 1975). In *Lamna nasus*, generally one to four embryos are found (Bigelow and Schroeder, 1948). Gohar and Mazhar (1964) counted six embryos in *Isurus oxyrinchus*, while Gubanov (1978) described up to ten embryos. In *A. vulpinus*, there are usually two embryos, one in each uterus (Bigelow and Schroeder, 1948; Strasburg, 1958; Gubanov, 1972).

The size of embryos recorded ranges from 33 to 36 cm in total length (Bass et al., 1975). The present four large embryos from a female 985 mm in total length measured from 401 to 428 mm. Judging from the smallest free-swimming size, 59 mm, obtained from the eastern Pacific (Abe et al., 1969), the present four embryos are probably full term embryos.

Bass et al. (1975) analyzed the stomach contents of a 17 cm long *O. taurus* embryo, and found a 40 mm embryo with a small yolk sac in the stomach. However, the present large embryos of *P. kamoharai* had neither egg capsules nor small embryos in the stomachs except for egg yolk material. According to Springer (1948), the stomach content of an *O. taurus* embryo was roughly estimated to be 28 ounces in volume. Cadenat (1956) examined the stomach and intestinal contents of a young free-swimming *O. taurus* weighing 8 kg which was probably born

shortly before the capture, and reported that the stomach contained about 1.5 kg of yolk material amounting to over 18% of the total weight. In *P. kamoharai* under study, egg yolk material in the stomachs occupied about 25% of the total weight of the body.

As regards to the sex of embryos of *P. kamoharai*, there is only one previous example. Bass et al. (1975) reported four female embryos in the uteri of a specimen collected from the southwest Indian Ocean. The present large embryos consist of one male and three females. Observations of 24 embryos in 12 litters of *O. taurus* by Sadowsky (1970) indicated that both sexes occurred in equal numbers. Gubanov (1978) reported that the sex ratio calculated in 80 embryos of *A. vulpinus* from the Indian Ocean was close to 1:1.

Each of the egg capsules presently observed contained more than one egg. There were from 2 to 9 eggs, 4 on the average, in a series of 15 egg capsules opened. Springer (1948) reported that in *O. taurus* each of the 10 egg capsules he examined contained from 16 to 23 ova with a mean of 19. In the case of *A. vulpinus*, judging from the illustrations of egg capsules given by Gubanov (1978), 25 or more ova are counted in an egg capsule.

With regard to the early development of embryos in *P. kamoharai*, no references have previously been reported. Bass et al. (1975) suggested that *O. taurus* embryos nourish themselves by feeding on ova in the uteri at a length of some 4 to 5 cm. The embryos of *P. kamoharai* examined in this study are about 40 mm in total length and showed no signs of feeding on ova in the uteri.

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中部太平洋産ミズワニにみられた卵食性の胎児

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1979年6月に中部太平洋海域において、鹿島丸(茨城県那珂湊水産高校所属)が延縄によってミズワニ11尾(雌3, 雄8)を漁獲した。全長985mmの雌の左右の子宮から401~428mmの範囲の胎児が2尾ずつ得られた。これらの胎児には臍帯は認められず、また、胎児の胃は著しく膨れ、その中には胎児の体重の約25%に相当する卵黄で満たされていた。これは、ミズワニの胎児が母体の子宮内に排卵された卵を食する卵食性の胎児であることを示している。また、全長982mmの雌の左右の子宮には卵黄囊をもつ胎児(全長37.9~40.8)が2尾ずつと多数の卵殻(右側の子宮内に21個、左側に23個)が見られた。これらの胎児は卵黄囊から卵黄の供給を受けており、まだ、親の子宮内に排卵された卵を食していない。

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